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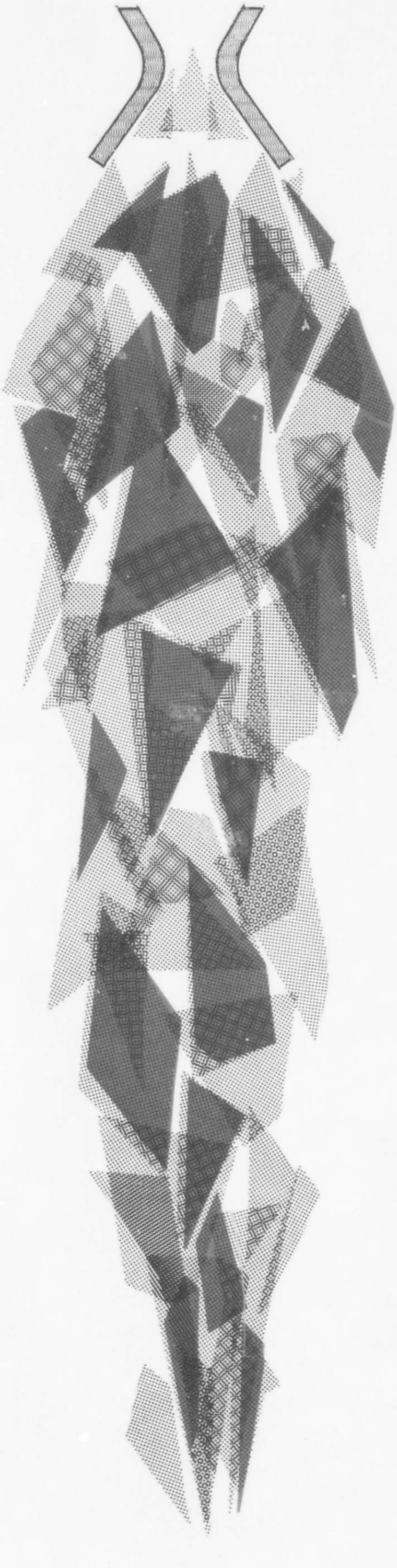

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REPORT NO. S-113

DEVELOPMENT OF A ROCKET MOTOR FOR CROW (U)

U. S. ARMY MISSILE COMMAND

ROHM AND HAAS
REDSTONE RESEARCH LABORATORIES
HUNTSVILLE, ALABAMA 35807

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ROHM AND HAAS COMPANY

REDSTONE RESEARCH LABORATORIES
HUNTSVILLE, ALABAMA 35807

Report No. S-113

DEVELOPMENT OF A ROCKET MOTOR FOR CROW (U)

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October 10, 1966

Contract No. DA-01-021 AMC-10037

TABLE OF CONTENTS

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REDSTONE RESEARCH LABORATORIES
HUNTSVILLE, ALABAMA 35807

DEVELOPMENT OF A ROCKET MOTOR FOR CROW (U)

ABSTRACT

A rocket motor for the CROW missile was developed in a time period of approximately four months. The motor was 2.54 inches in diameter and 20 inches in length. The motor contained 3.1 pounds of plastisol nitrocellulose composite propellant in a rod-and-tube grain design and weighed six pounds ready to fire. The high-strength steel case and aluminum nozzle were insulated to prevent excessive heating of the motor case.

Nineteen motors were static tested and five were successfully flight tested at accelerations of approximately 110 g's. The motor produced an average thrust of 4300 for a burning time of 175 msec, and delivered a total impulse of 805 lbf-sec/lbm. The operating pressure was 4000 psia.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Mr. Ed Blackman, CROW Project Director, Picatinny Arsenal, for the fine working relationship maintained between our organizations. The advice of Mr. H. Williams and support of Mr. W. E. Thomas of the U. S. Army Propulsion Laboratory, Redstone Arsenal, are greatly appreciated. Mr. H. Griffith of Ground Support Laboratory, Redstone Arsenal was also very helpful.

Finally, a special thanks to employees at Redstone Research Laboratories for their hard work, without which the completion of this program in such a short time would not have been possible.

ROHM AND HAAS COMPANY

REDSTONE RESEARCH LABORATORIES
HUNTSVILLE, ALABAMA 35807

DEVELOPMENT OF A ROCKET MOTOR FOR CROW

1. INTRODUCTION

The Combined Rocket-Warhead (CROW) is a concept for an artillery rocket in which the rocket motor propulsion unit is embedded inside the high explosive warhead (Figure 1). This configuration gives the advantages of a shorter length round without reducing effectiveness. Successful demonstration of such a design depends on maintaining reasonable temperatures on the motor case to prevent ignition or degradation of the high explosive during flight to the target.

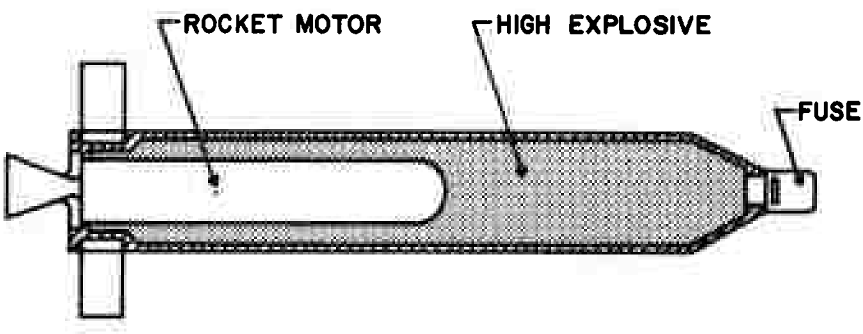


FIG. 1 COMBINED ROCKET-WARHEAD (CROW) CONCEPT.

In September, 1964, these Laboratories completed a program which demonstrated that a total impulse of 400 lbf-sec could be delivered from a motor 2.2 inches O. D. × 11.5 inches long (1)[1]. This first CROW motor used a slotted-tube grain design which required considerable insulation to prevent the case from exceeding a 200° F temperature rise. In March, 1966, a second contract was awarded these Laboratories to develop a larger motor for flight tests. The contract was to be completed and four motors delivered by July, 1966. This is the final report of Contract No. DA-01-021 AMC-10037.

2. MOTOR CHARACTERISTICS

The performance requirements for the larger motor as they evolved during the program are given in Table I. Following parametric studies and discussions with the Picatinny Arsenal representative, the motor diameter was set at 2.54 inches and the length was limited to about 16 inches, excluding nozzle. These dimensions were based on preliminary designs which used a propellant loading fraction of 80%. Operating temperature range for the motor was set at 70° F to 110° F.

Table I

CROW Motor Requirements

Total Impulse	800 lbf-sec
Total Weight	6.0 lbm
Burning Time, t_b	180 msec
Minimum Average Thrust	4000 lbf
Average Chamber Pressure, $\overline{P}_b$	4000 psia
Maximum Case Temperature at 30 sec	280° F

[1]Numbers in ( ) parentheses indicate references listed at end of Report.

3. BALLISTIC DESIGN AND TESTING

3.1 Selection of Grain Configuration

Propellant burning rate received first consideration in the initial grain design studies for the CROW motor. Some propellants showed promise of exhibiting rates of 3.5 in/sec at 4000 psi. However, these propellants were not state-of-the-art and required further development. Due to the limited time in the program, a well-characterized plastisol-nitrocellulose composite propellant was chosen. This propellant, RH-P-112ci, provided a burning rate of approximately 2.5 in/sec at 4000 psia (See Propellant Development for further discussion).

Three grain designs were given primary consideration for use in the CROW motor. Table II shows a comparison of the star, slotted-tube, and rod-and-tube designs. The numbers are based on a burning rate of 2.50 in/sec, a chamber pressure of 4000 psia, and a propellant loading fraction of 80%.

Table II

CROW Grain Design Comparison

Grain	Burning Time (msec)	Throat to Port ratio	Sliver Fraction (%)	Thrust (lbf)	Chamber Pressure (psia)
Rod-and-tube	186	0.50	0	4300	4000
Star	199	0.74	10	4020	4000
Slotted-tube	300	0.45	0	2730	4000

Both the rod-and-tube and slotted-tube had zero sliver which was desirable. However, the web thickness of the slotted-tube grain was large, giving a long burning time and a low thrust. The disadvantages of the star configuration (Figure 2) were the high initial J, and the large sliver fraction. The rod-and-tube design had neither of these problems and in addition had very low insulation requirements, while the star and slotted-tube grains required case wall insulation to prevent excessive heating.

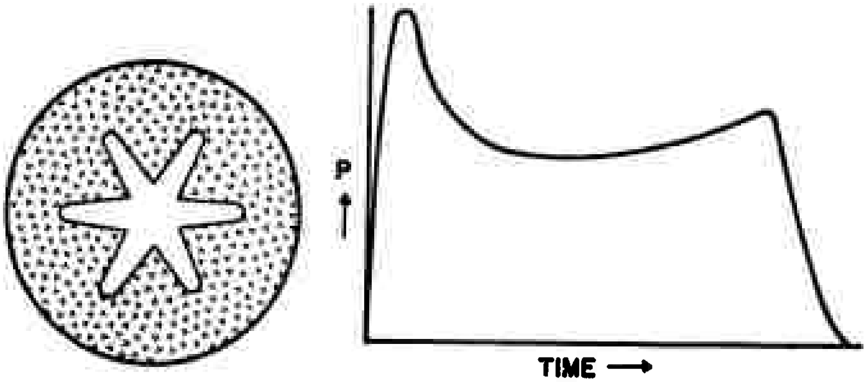


FIG. 2 STAR GEOMETRY AND MOTOR PRESSURE TRACE.

Preliminary static tests were run on the star geometry and the rod-and-tube design in scale two-inch hardware. With the star grain, high pressure peaks resulted from erosive burning and dynamic pressure drop at high J's (Figure 2). Test results using a scale rod-and-tube design were encouraging with high integral ratios and low values of $P_{max}/\overline{P}_b$ (Table III). Both test designs approximated the CROW motor requirements but the superiority of the rod-and-tube design was obvious.

Table III

Summary of Grain Evaluation Firings

Round Number	Grain Design	Average Pressure, $\overline{P}_b$ (psia)	$P_{max}/\overline{P}_b$	Integral Ratio	Burning Time (msec)
5905	Rod-and-Tube	3818	1.07	0.93	152
5979	Rod-and-Tube	3858	1.06	0.95	155
6357	Star	4780	1.14	0.85	133
6358	Star	5097	1.54	0.86	135

The rod-and-tube design had a disadvantage in that the support of the propellant could introduce high stresses under high acceleration. However, preliminary calculations showed that the stresses were within the propellant capability.

Following these preliminary studies, the rod-and-tube grain design was chosen for the CROW motor. Figure 3 shows the complete grain design and motor hardware. Predicted motor performance and total weight are shown in Table IV.

Table IV

Predicted CROW Motor Performance and Weights

Total motor weight, lbm	6.0
Total propellant weight, lbm	3.1
Burning time, t_b msec	185
Average pressure, $\overline{P}_b$ psia	4000
Average thrust, lbf	4300
Total impulse, lbf-sec/lbm	800
Initial J (at aft end of rod)	0.47

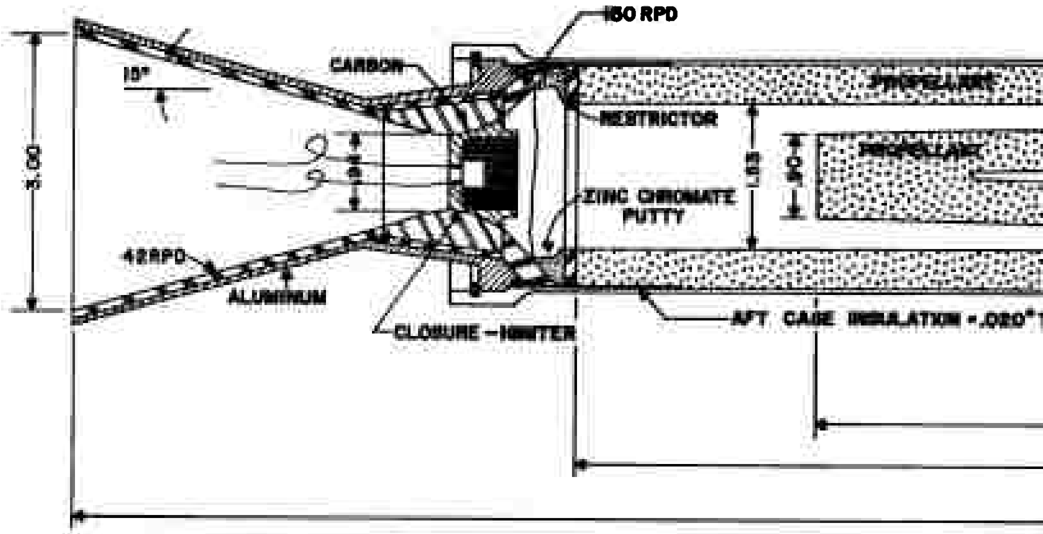
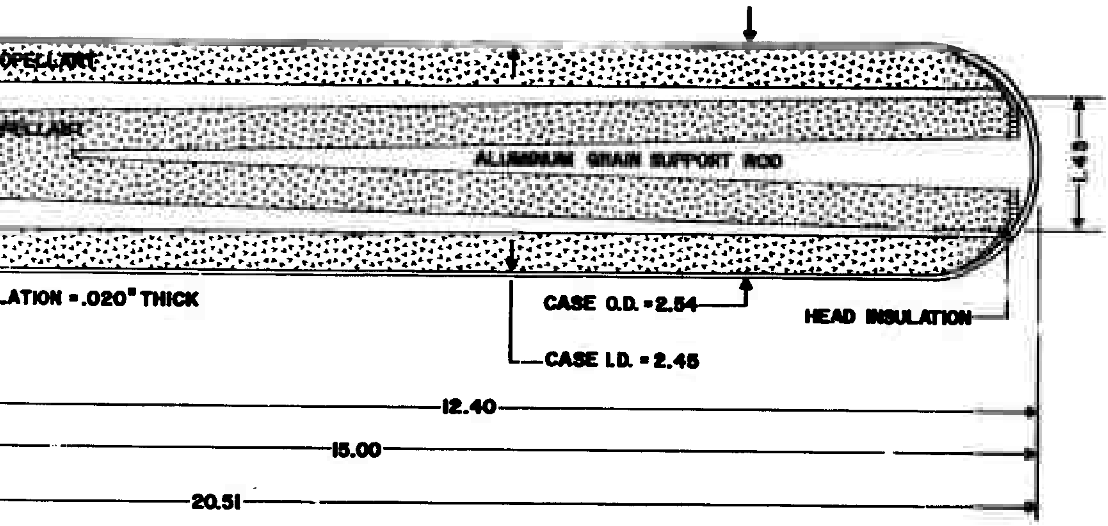


FIG. 3 CROW MOTOR DESIGN FEATURES.



OPELLANT
PELLANT
ALUMINUM GRAIN SUPPORT ROD
1.40
LATION =.020" THICK
CASE O.D. =2.54
HEAD INSULATION
CASE I.D. =2.45
12.40
15.00
20.51

3.2 Ignition System

The nozzle closure (Figure 3) for the CROW motor was adapted from closures made for a shoulder-fired rocket motor. A series of firings in 2-inch motor hardware was conducted to determine the blow-out pressure. With a slight thinning of the retainer flange, the closure blew out at approximately 3000 psia which was the desired pressure for the CROW motor. The igniter powder cavity in the closure was also found adequate to hold the three grams of igniter powder and squib. The sizing and type of igniter powder (Table V) were based on the experimental grain design tests. Three grams of RHIM-1 and a standard M-3 squib provided very satisfactory ignition.

Table V

Composition of Rohm and Haas Igniter Mixture 1 (RHIM-1)

Magnesium powder[a]	60%
$KCLO_4$[a]	25%
$BaNO_3$[a]	15%

[a] All components 140-270 mesh

4. HARDWARE DESIGN AND FABRICATION

4.1 Design Details

The CROW motor case was a closed-end tube with hemispherical head end to mate with the cavity in the high-explosive-filled warhead. The case was fabricated from AISI 4140 steel which was heat treated to provide a yield strength of 160,000 psi. Design internal pressure of the motor was 5000 psi maximum. The aluminum nozzle was retained by a heavy-duty snap ring.

An aluminum grain support rod was bonded into the head end of the motor with epoxy cement underneath a molded cap of asbestos-phenolic insulation. Insulation was also provided under the grain-nozzle junction to prevent case heating. The major portion of the case was uninsulated.

Compression-molded asbestos-phenolic insulation protected the nozzle housing from the hot propellant gases. The converging face was machined from a billet of 150 RPD[1]. Both Graphitite A[2] and AHDG[3] carbon were used successfully as carbon inserts. Figure 3 shows the details of the inert hardware design.

With the aid of a digital computer, a finite element method of stress analysis was used to check the nozzle design, which proved adequate in all areas. The most critical point was at the aft end of the carbon; the calculated stresses were 4000 psi while the predicted failure point was 5000 to 6000 psi.

4.2 Hardware Fabrication

All hardware for the CROW motor was manufactured at the Redstone Research Laboratories. Fabrication of the motor case began with the machining of the hemispherical head end from a short billet and the inside diameter of the tubular section. These two parts were then welded together by an inert-gas-shielded automatic feed welding head and heat treated immediately thereafter. The outside of the case and the nozzle seating area were machined as the final step. An expanding mandrel was used inside the motor during the final cut to insure a uniform wall thickness of 0.045 inch. A Rockwell C hardness of 37 was obtained in the motor walls which indicates a yield strength of approximately 160,000 psi and a safety factor of 1.28 at an internal pressure of 5000 psia.

---

[1]Raybestos Manhattan, Inc., Manheim, Pennsylvania.
[2]Basic Carbon Corp., Sanborn, New York.
[3]American Metal Products Co., Eng. Science Div., Ann Arbor, Michigan.

The nozzle exit cone and throat insulation, and motor head insulation cap were molded from 42 RPD[1] using matched metal molds. An initial cure of 30 minutes at 1000 psi and 300°F was followed by a post cure of 24 hours at 300°F. The molded parts are shown in Figure 4 lined up in order of assembly into the motor and nozzle. The aft motor case insulation was bag molded into the case to an initial thickness of 0.030 inch and machined to a thickness of 0.020 inch. Cure cycle consisted of one hour at 100 psi and 300°F followed by 24 hour post cure at 300°F.

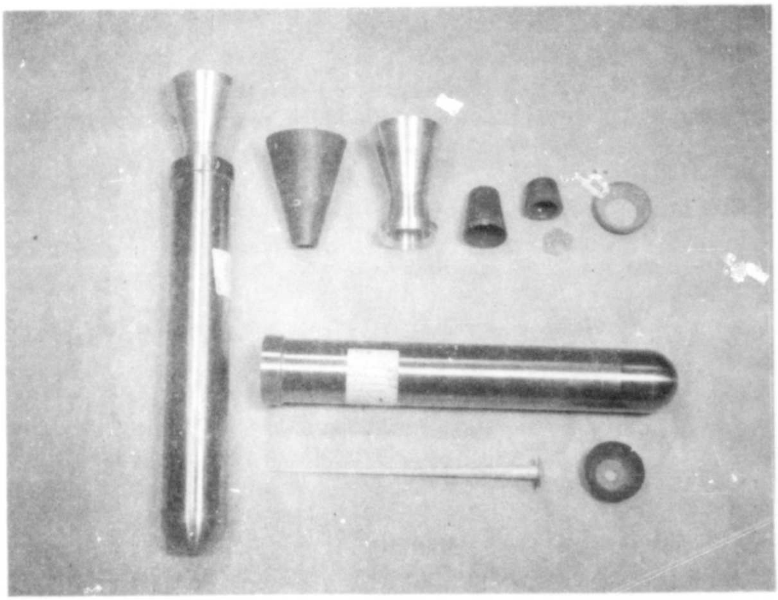


FIG. 4 PHOTOGRAPH OF CROW MOTOR PARTS.

[1]Raybestos Manhattan, Inc., Manheim, Pennsylvania.

The nozzle housing was machined from 7075-T651 aluminum and the converging face from 150 RPD. An epoxy cement[1] was used to bond the insulation and carbon into the nozzle housing.

5. PROPELLANT AND RESTRICTOR DEVELOPMENT

At the beginning of the effort, the high-rate carboxyl-terminated propellant intended for this motor was not ready for application and the development schedule extended beyond the period of performance for the CROW motor development. In order to eliminate propellant processing and development problems from the program, a well-characterized Rohm and Haas propellant, RH-C-112 (Table VI), was selected. This plastisol-nitrocellulose composite propellant used 5 micron ammonium perchlorate to achieve a burning rate of approximately 2.50 in/sec at 4000 psia. The propellant was mixed as a slurry, easily cast into the motor, and had adequate physical properties for the CROW motor application (Table VII).

Table VI

Composition of Rohm and Haas Company Propellant RH-P-112ci

Ingredient	Weight Percent
Double base powder	16.67
Triethylene glycol dinitrate	37.33
NH_4ClO_4 (5 micron)	30.00
Aluminum	15.00
Resorcinol	1.00

Table VII

Physical Properties of RH-P-112 (@77°F)

Tensile Strength	58 psi
Elongation	20%
Density	1.665 g/cc

[1]Epon 828, Shell Chemical Company, New York, New York.

Routine burning rate checks were made on each batch of propellant cast into CROW motors using the Rohm and Haas 2C1-4 static test motor. Early rate data on which the motor design was based were slightly lower than that of the propellant which actually went into the motors. This change in rate occurred as a result of a change in ammonium perchlorate grind. However, all CROW motor propellant was made from one grind and the burning rates were reproducible (Figure 5).

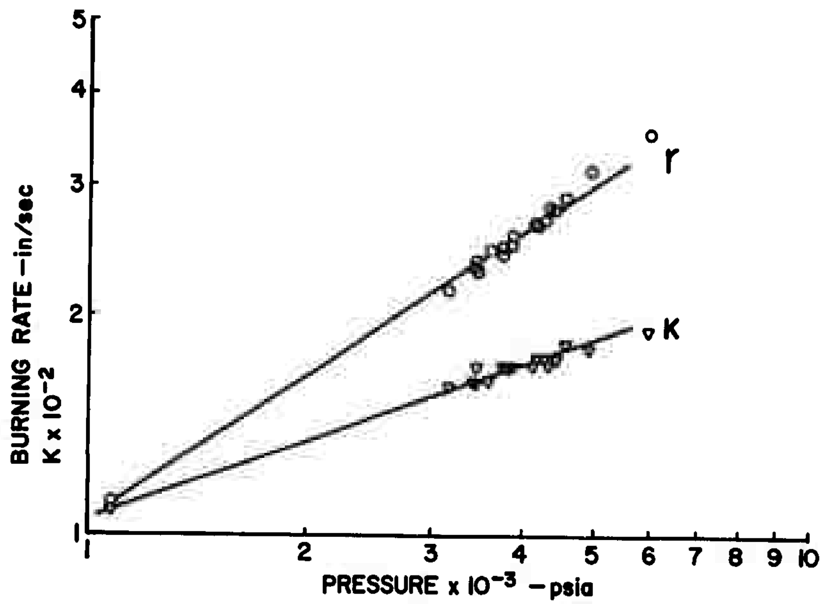


FIG. 5 P-K-r DATA FOR RH-P-112cl.

An aft grain restrictor was used on the tube grain to provide a neutral surface-time history. The restrictor, PR-47, was based on a similar material used in a previous program (2). PR-47 had the same ball powder/plasticizer ratio as the propellant which prevented plasticizer migration. Asbestos powder was added to lower the burning rate and to serve as a thickener during application and curing (Table VIII).

Table VIII

Restrictor PR-47 Composition

Double base powder	25%
Triethylene glycol dinitrate	60%
Ground asbestos[a]	15%

[a]TF 7-1, Johns-Manville, 22 E. 40th St. New York, New York

The restrictor's burning rate at 4000 psia was less than 0.625 in/sec (1/4 of the propellant burning rate) so that a restrictor thickness of 1/8 inch (1/4 of the propellant web) was adequate.

All surfaces inside the motor were grit-blasted, vapor degreased, and coated with PL-1 liner (Table IX) prior to propellant casting. Bonding tests were run on each combination of materials and the results in all cases showed excellent bonding (Table X).

Table IX

Formulation of PL-1 Liner

Ingredient	Weight Percent
Cellulose Acetate	48.4
Triphenyl Phosphate	30.5
Santicizer M-17[a]	18.4
Toluene Diisocyanate	2.4
Red Lead	0.24
Acetone (ml/100 gm dry ingredients)	615
Methyl"Cellosolve"Acetate (ml/100 dry ingredients)	484

[a]Monsanto Chemical Co., St. Louis, Missouri
[b]Union Carbide Corp., New York, New York

Table X

CROW Insulator-Propellant-Restrictor Bond Tests

Substrate	Restrictor	Pull Strength[a] (psi)	Comments
RH-P-112	PR-47	20	The samples broke in the propellant with a tearing effect.
42-RPD	PR-47	25	Peeled at the restrictor/substrate interface. Small pieces of 42-RPD were left bonded to the restrictor.
42-RPD/PL-1	PR-47	23	Peeled at the PR-47/PL-1 interface.

[a]Each value is the average of two samples tested at 77°F.

6. MOTOR PREPARATION, CASTING, INSPECTION AND ASSEMBLY

The manufacturing cycle for the CROW motor required approximately five days from initial sandblasting to final loading for firing. A detailed insight into the number of steps may be seen in the motor preparation and inspection sheets shown in Appendix A. These sheets were used to insure proper monitoring of the work.

In brief, the preparation of the motor was as follows:

1. Sandblasting and degreasing - The motors were blasted internally with metal shot to remove scale and provide a clean surface for bonding. Following degreasing in trichloroethylene, the motors were stored at 140°F to prevent rusting until the next operation.

2. The aft insulation was molded in place and machined to diameter. Following the 24 hour post cure, the motor was again degreased and stored at 140°F.

3. Installation of the head insulation cap and grain support rod was accomplished in one operation using a special aligning tool. The epoxy resin[1] was cured 8 hours.

4. PL-1 liner was applied to the motor by the dipping technique. This procedure consists of filling the motor to coat the walls, pouring out the excess and allowing the motor to drain while inverted. The liner was cured one hour at 140°F.

5. Motors were weighed before being sent to propellant casting. Figure 6 shows the insertion-type mandrel and casting fixtures which were used. In this technique, the casting head and base are attached to the motor and the propellant is poured in. The mandrel is then inserted. This method makes casting of thick propellants less difficult and reduces air entrapment in the propellant. Following casting, the propellant was cured approximately 16 hours at 120° F.

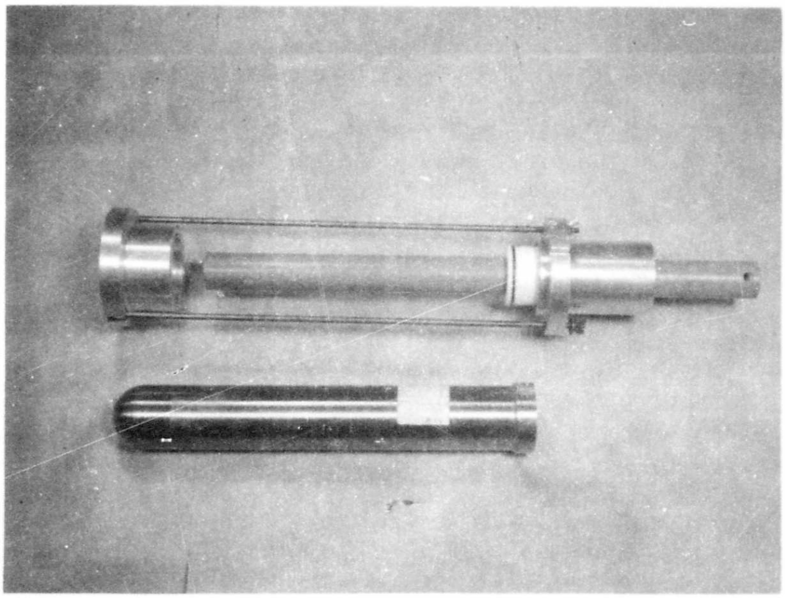


FIG. 6 PHOTOGRAPH OF CASTING FIXTURES.

[1]Epi-Rez Epi-Cure; Jones Dabney, Louisville, Kentucky.

6. X-ray inspection was the primary inspection tool, but visual inspection was also used. Figure 7 shows a typical x-ray photograph. Following inspection, the grain was trimmed to length and the PR-47 restrictor applied and cured 16 hours at 110° F.

7. Nozzle installation completed the motor for firing. The nozzle closure-igniter was bonded into the converging section using Pliobond[1]. In addition to the O-ring seal between nozzle and motor, zinc chromate putty[2] was packed at the forward end of the nozzle (Figure 3). This material prevented the hot gases from reaching the O- ring. It had the disadvantage of absorbing plasticizer from the restrictor and therefore could not be used for long term storage.

7. STATIC TESTING

7.1 Ballistic Evaluation

Initial testing of the CROW motor began in a heavy-wall motor which was identical internally to the flight case. The wall thickness, however, was 0.120 inches and the head end incorporated pressure ports. The heavy-wall motors were used for nozzle sizing and igniter and grain evaluation since pressure measurement was not possible in flight cases. Six heavy-wall motors were fired; thirteen flight-weight motors were static tested.

Static test data are summarized in Table XI and Figure 8 shows a typical thrust-time history. Average motor performance is given in Table XII. The total impulse requirement of 800 lbf-sec was met and the burning time was less than 180 msec.

[1]Pliobond Super Glue, The Goodyear Tire & Rubber Co., Akron, Ohio.
[2]W. P. Fuller & Co., San Francisco, California.

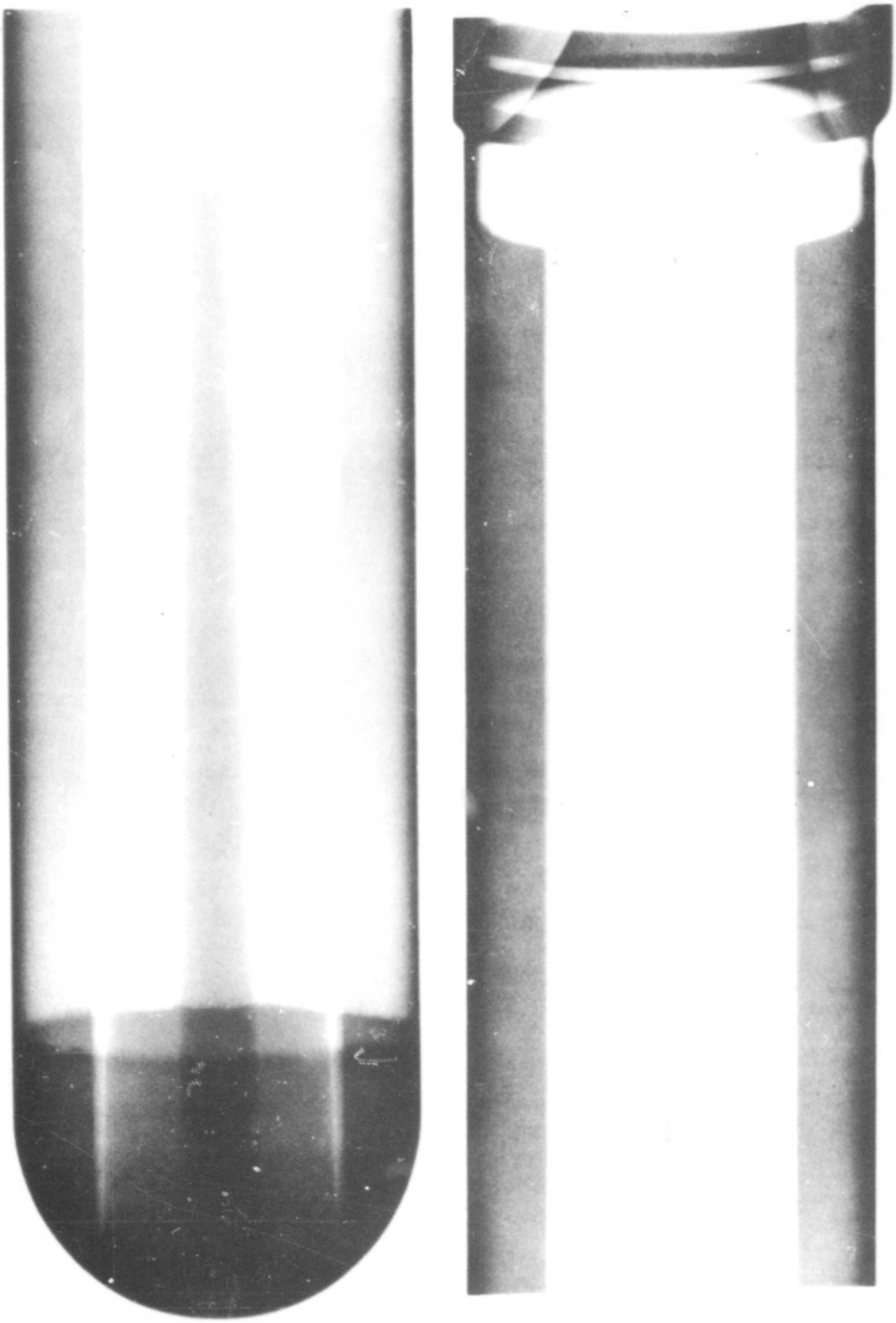


FIG. 7 TYPICAL X-RAY FILM OF CROW MOTOR.

Table XI

CROW Motor (2.5 RT 16) Static Firing Data Summary

Round	Case	Propellant Weight (lbm)	t_a (msec)	P_a (psia)	F_a (lbf)	I_{spd} (lbf-sec/lbm)	I (lbf-sec)	∫Ratio	T^a °F
6841	Static	3.03	178	3868				0.94	
6861	Static	3.05	187	3743	4081	261	797	0.95	
6862	Flight	3.06	184		4361	263	805		124
[illegible]	Static	3.01	198	3516	3657	261	786	0.96	
6892	Static	Overpressured on Ignition							
6893	Flight	3.05	208		3783	258	787		131
6920	Static	2.99	Nozzle Throat Blew Out						
6921	Static	3.04	196	3599	3844	262	795	0.95	
6962	Flight	3.06	204		3750	263	806		232
6963	Flight	3.07	200		3711	263	809		241
[illegible]	Flight	Case Overheated and Ruptured at 100 msec Due to Aft Restrictor Failure							
6990	Flight	3.07	210		3661	262	803		193
7006	Flight	3.06	210		3611	263	805		193
7007	Flight	3.07	210		3743	256	786		189
7008	Flight	3.07	214		3736	260	799		163
7038	Flight	3.07	203		3752	262	805		154
7039	Flight	3.08	195		3920	262	807		167
7040	Flight	3.08	194		3947	262	807		189
7041	Flight	3.07	201		3803	262	805		176

[a] Maximum temperature on motor case (at aft flange) at 30 seconds after firing.
Rounds 6962, 6963, 6990 had partial aft restrictor failure.
Rounds 7007, 7008 had a low measured impulse due to a thrust gage problem.

Table XII

Typical Performance for CROW Motor

Total motor weight including nozzle, lbm	6.0
Total propellant weight, lbm	3.07
Burning time, msec	175
Average pressure, t_b psia	4000
Average thrust, lbf	4300
Total impulse, lbf-sec	805

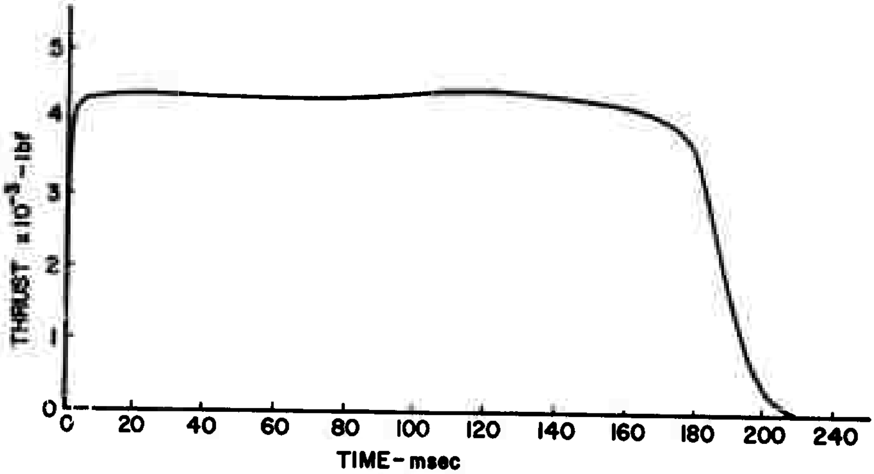


FIG. 8 TYPICAL CROW MOTOR THRUST-TIME HISTORY.

7.2 Case Temperature Measurements

Motor case temperatures were measured for 30 seconds following firing of flight weight cases. Thermocouples were welded to brass shim stock which was then taped to the case wall. Asbestos sheet insulation was used to cover the thermocouples and motor during and after firing in order to obtain the worst condition.

A typical temperature history is shown in Figure 9. The maximum temperature occurred on the aft flange of the motor due to heat input by the nozzle. Except in motors with aft restrictor failure, the maximum case temperature remained below 200°F (Table XII).

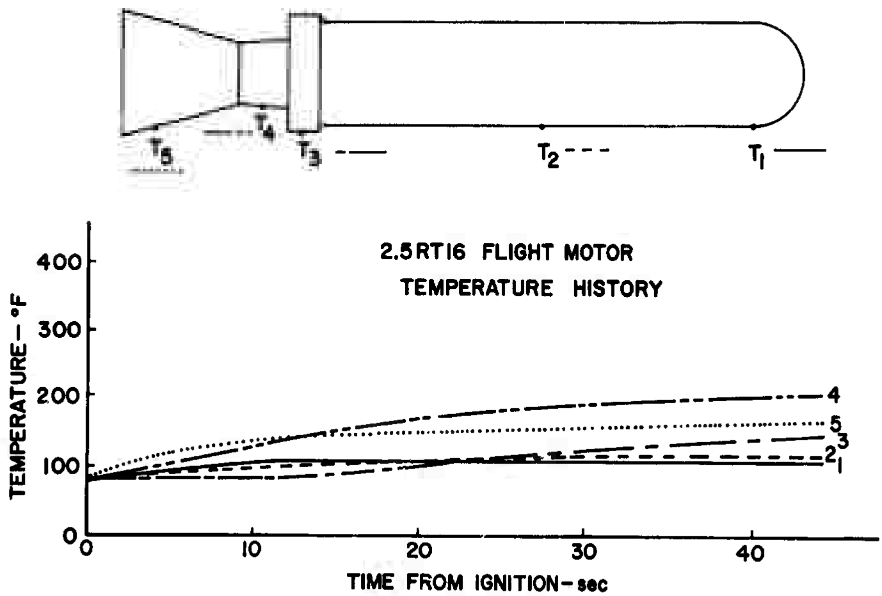


FIG. 9 TYPICAL CROW MOTOR CASE TEMPERATURE HISTORY.

7.3 Development Problems

Failure of the aft restrictor was one of two problems encountered during the program. This failure resulted in the rupture of two motor cases (Table XII, rounds 6892 and 6989). The restrictor failure was traced to poor quality control in the mixing and application of the restrictor itself. The procedures were revised to use a more uniform void-free technique and the problem was solved.

The second problem was break-up of the nozzle carbon insert. During early ballistic evaluation in heavy-wall motors, the throat size was increased from the original design in order to obtain the proper burning pressure. The revised nozzle throat contour resulted in a very thin section at the aft end of the carbon insert. After this trouble was discovered the contour was again revised to give the proper carbon throat diameter and a thicker aft end.

No failures occurred subsequent to this change in the nozzle contour and the revision in the restrictor application procedures (Table XII, round 7006 and subsequent).

7.4 Centrifuge Tests

Centrifuge tests were run as a confirmation to the grain stress calculations with respect to the flight acceleration. The motor withstood an axial acceleration of 75 g's for 10 minutes with no sign of damage. The two motors which were centrifuged were later successfully static tested (Table XII, rounds 6920, 6921).

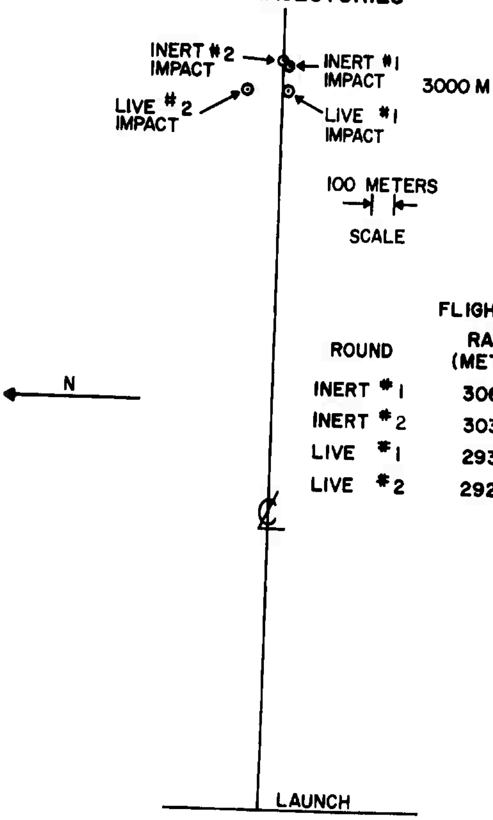
7.5 Flight Tests

Five motors were flight tested; one at Redstone Arsenal and four at Yuma Proving Grounds, Yuma, Arizona. The last two shots at Yuma were with live warheads.

The CROW missile fired at Redstone Arsenal was not recovered for inspection. However, films of the flight showed that the motor performance was satisfactory. The first two missiles at Yuma contained inert warheads and hence, the rounds were recovered for inspection. These motor cases were very similar to a statically tested motor.

High speed motion pictures of the flights correlated well with the motor inspections; i.e., motor performance was satisfactory.

Final confirmation of satisfactory motor performance was the flight data on the Yuma missile firings. Figure 10 shows a plan view of the range, launch, and impact points. Trajectory analysis showed that the missile range with a motor giving 800 lbf-sec of impulse should be approximately 3000 meters.



FLIGHT DATA

ROUND	RANGE (METERS)	DISPERSION (METERS)
INERT #1	3068	14 LEFT
INERT #2	3034	36 RIGHT
LIVE #1	2936	34 RIGHT
LIVE #2	2928	155 LEFT

FIG. 10 RESULTS OF CROW FLIGHT TESTS.

REFERENCES

1. S. E. Anderson, et al., "Demonstration of a Propulsion Unit for the Combined Rocket-Warhead (U)," Rohm and Haas Company Special Report S-52, September 22, 1964.

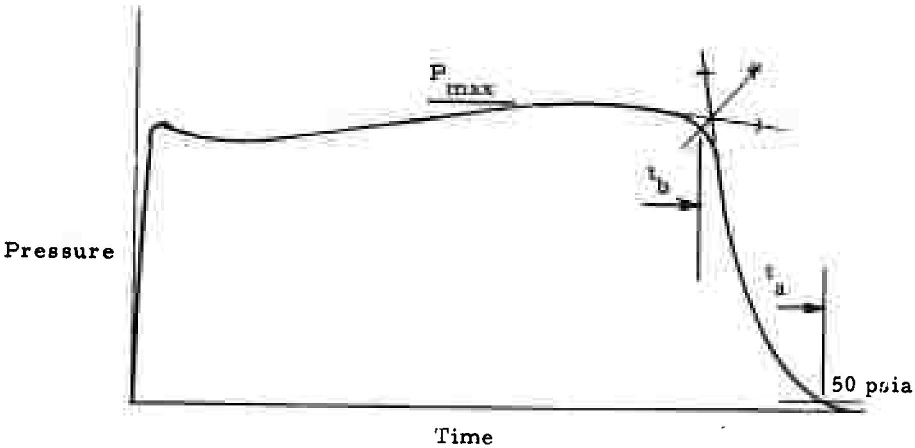
2. Development of a Booster Motor for Missile A, Quarterly Progress Report on Interior Ballistics, Rohm and Haas Company Report No. P-60-19, January 1961.

APPENDIX A

2.5 RT-16
MOTOR PREPARATION
AND
INSPECTION SHEETS

GLOSSARY OF BALLISTIC TERMS

Ballistic terms which are used in this report are defined below.



t_b	burning time - time from ignition to end of web burning
t_a	action time - time fron ignition to point at which pressure reaches 50 psia during tail-off
$\overline{P}_b$	average pressure over burning time
$\overline{P}_a$	average pressure over action time
Integral Ratio	the ratio of the area under the pressure time curve out to t_b to the total area under the pressure time curve. A measure of the sharpness of the tail-off
I	total impulse - area under thrust versus time curve
I_{spd}	specific impulse delivered at firing conditions - I/propellant weight

Motor Dimensions and Hydrotest

Instructions:

1. Attach metal numbering tag to motor

2. Measure and record dimensions of motor

Motor No.	______
Motor Weight	______
Motor Length	______
Max. Tube Diameter	______
Min. Wall Thickness	______
Out of Round	______
Aft Tube Diameter	______

3. Hydrotest to 5000 psig

Hydrotest Pressure	______
Time at Pressure	______
Date	______
Work by	______
Inspected by	______

Motor dimension and hydrotest
Sheet 1

Sandblasting

Instructions:

1. Cover inside of case from aft end forward for one inch.
2. Sandblast inside of case until rust, dirt, and glass are removed from surface. Use caution not to overblast and cause metal removal.
3. Wash and degrease for ten minutes.
4. Store in hot room until ready for next operation.

Data:

Motor No.	____________
Sandblasted by	____________
Inspected by	____________
Date	____________

Remarks:

Sandblasting

Sheet 2

Aft Insulation Molding

Instructions:

1. Cut a sheet of 42 RPD $1\frac{5}{8}$" × $15\frac{1}{2}$" roll into place in motor as shown in Rohm and Haas Drawing RC-7195.
2. Assemble rubber tube on aft molding fixture and clamp and glue forward end of tube. Cut tube 16" long.
3. Place fixture and tube in motor and pressurize to 125 psi. Cure in 300°F oven for one hour.
4. Remove motor from oven and measure pressure. Remove molding fixture from motor. Measure I. D. of insulation.

Data:

Motor No.	______________
Time in oven	______________
Time out	______________
Pressure in	______________
Pressure out	______________
I. D. of insulation	______________
RPD lot	______________
Work by	______________
Inspected by	______________
Date	______________

Remarks:

Insulation Molding

Sheet 3

Rod Support and Insulation Installation

Instructions:

1. Sandblast the premolded 42 RPD head end insulation cap and the grain support rod. Bond the two together using the following resin

Epirez	504	75%
Epicure	855	25%
Benton	27	Thicken to paste

2. Cure this joint for 6 hours at 150°F.

3. Bond the rod-cap sub-assembly into the motor using the special installation tool and the same resin. Use care to prevent overflow of excess resin.

4. Cure for 6 hours at 150°F

Data:

Motor No. __________

Work by __________

Date __________

Inspected by __________

Remarks:

Assembly

Sheet 4

Lining

Instructions:

1. Place tape over the steel surfaces aft of the molded insulation in the motor (approx. 1"). Preheat the motor to 140-150°F.
2. Pour approximately 200 ml. of PL-1 liner into the motor and manipulate the motor until all surfaces have been coated.
3. Pour out excess and set motor up to drain in a 140-150°F atmosphere. Allow to cure for 2 hours.
4. Remove tape from aft end and weigh.

Data:

Motor No.	____________________
Work by	____________________
Weight	____________________
Date	____________________
Inspected by	____________________

Remarks:

Trimming and Restricting

Instructions:

1. After motor returns from casting and x-ray, obtain approval from supervisor before proceeding. X-ray inspection ________________ by _______________.

   Remarks:

2. Trim off excess propellant from cylindrical part of grain. Weigh motor and record weight. Weight before restriction __________________.
3. Apply $\frac{1}{8}$ inch of PR-47 restrictor to aft end of cylindrical grain. Restrictor weight ________________.
4. Cure restrictor at 110°F for 16 hours.
5. Install four foam rod supports using Pliobond to glue in place near the aft end of rod.

Data:

Motor No.	________________
Work by	________________
Date	________________
Inspected by	________________

Remarks:

Nozzle

Instructions:

1. Etch number on exit cone of nozzle.
2. Sandblast I.D. of nozzle housing and plastic parts.
3. Bond in carbon throat insert and insulation.
4. Machine insert to length. Machine mating diameter of converging face and exit cone. Se RC-7199.
5. Bond in exit cone and converging face insulation.
6. Trim to length.
7. Record the following dimensions

Nozzle length	____________
Max. O.D.	____________
Exit diameter	____________
Throat diameter	____________
Weight	____________
Nozzle No.	____________

Nozzle

Sheet 7

Loading

Instructions:

1. Assemble a T-205 closure with 3 grams of RHim and an M-3 squib.
2. Bond the closure in the nozzle converging face with Pliobond.
3. Grease and install the nozzle "O" ring on the nozzle.
4. Place a 1/4 inch diameter ring of zinc chromate putty at the aft end of the grain so that the nozzle converging face will engage it when installed. Grease the steel surfaces aft of the zinc chromate putty.
5. Insert nozzle into motor and install snap ring.

Data:

Nozzle No.	______________
Motor No.	______________
Work by	______________
Nozzle throat diameter	______________
Date	______________
Exit diameter	______________
Inspected by	______________
Total motor weight	______________

Remarks:

Firing
Instructions:

1. Tape thermocouples on motor at locations specified on firing sheet.
2. Assemble special thrust harness with motor and connect to a 5K thrust gage and universal joint. Place yokes at aft end of motor.
3. Connect lines to motor strain gage and to thrust gage. Connect thermocouples.
4. Proceed with firing by SOP for E-Range.
5. After shot, cut oscillograph speed down and continue recording for one minute to check thermocouple measurement of motor temperature.

Data:

Time in conditioning	____________	hrs.
Temperature	____________	
Motor No.	____________	
Work by	____________	
Date	____________	
Inspected by	____________	

Firing
Sheet 9

Initial distribution of this report has been made in accordance with "Chemical Propulsion Mailing List," CPIA Publication 74, March 1965, and approved supplements.

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